NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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AN ANALYSIS OF THE LAND IMPACT PROBLEM DURING MODE I ABORTS FROM THE SATURN IB LAUNCH VEHICLE

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PROJECT APOLLO

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FIGURES

AN ANALYSIS OF THE LAND IMPACT PROBLEM DURING MODE I ABORTS FROM THE SATURN IB LAUNCH VEHICLE

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SUMMARY

Mode 1 aborts from the Saturn IB launch vehicle have been studied to evaluate the land impact problem. Both statistical wind data and measured wind data were used. The study shows that the possibility of a landing exists and depends greatly on the wind velocity and azimuth.

INTRODUCTION

This document presents an evaluation of the land impact problem during mode 1 aborts using the launch escape vehicle (LEV) from the Saturn IB vehicle, which is launched from pad 34.

Recently flight crew personnel changed the abort sequence for mode 1 (LEV) aborts occurring from 10 to 40 seconds flight time from deploying main chutes manually at an altitude of approximately 2800 ft to deploying them automatically at 28 seconds after the abort occurs. The original procedure of delaying main chute deployment until approximately 2800-ft altitude (ref. 1) was initiated to eliminate land landing after an abort with a reasonable wind restriction (i.e., one that would not hold the mission) on manned missions. This procedure was referred to as "sky diving" and minimized driftback of the command module (CM) under the influence of a headwind. However, elimination of the "sky dive" mode enhances land landing probability and greatly increases the wind restriction on manned missions.

ANALYSIS

The analysis was conducted using the AS-204 launch vehicle operational flight trajectory (ref. 2) and the mission data specification document (ref. 3).

The abort sequence of events used are the same for Canard deployment, tower jettison, and drogue chutes deployed (AS-204 abort document, ref. 4).

The sequences used for deploying main chutes (ref. 5) are the following:

Mode	Time of abort	Main chutes deployed
1	0 to 10 seconds	Approximately 2800-ft altitude
1a	10 seconds through 40 seconds	28 seconds
1b	Approximately 41 seconds to 61 seconds	10 500-ft altitude
1c	61 seconds to 100 000-ft altitude	10 500-ft altitude

These are shown in figure 1.

Wind Data

To evaluate the possibility of a land landing from mode 1 (LEV) aborts, some standard of wind velocity and azimuth that would influence the abort trajectory had to be established. The principal source of wind data available and used for this document is statistical wind data (ref. 6). Other wind data used is measured wind profile data from the Gemini IX and Gemini X missions (ref. 7 and 8).

Statistical wind data.- The statistical wind data were from rawinsonde observations taken twice daily over a period of 8 years (January 1, 1956 through December 31, 1963). Observations from January 1, 1956 to November 17, 1956, were at Patrick AFB, Florida, latitude 28°14' N, longitude 80°36' W. Observations from November 18, 1956 to December 31, 1963, were at Cape Kennedy, Florida, at latitude 28°29' N, longitude 80°33' W.

The data presented in reference 6 were the cumulative percentage frequency of occurrence of computed wind components (head and tailwind, right and left crosswind) for increments of 15° of flight azimuth, figure 2.

Onshore winds nearly perpendicular to the shoreline in the launch site area are most undesirable for early mode 1 (LEV) aborts.

Therefore, the statistical wind data used for this study is for a headwind (onshore) and a 75° flight azimuth (nearly perpendicular) with no crosswind. Figure 3 presents the measured headwind components for each month and indicates that the wind velocity for 99 percent of the total number of observations for each month were equal to or less than the wind velocity shown.

Statistical headwind components were averaged for each month to determine the least and most favorable months for mode 1 (LEV) aborts.

Figure 4 presents the average headwind components. These averaged data are the equivalent steady state velocity from a specific altitude to the surface. It was determined that for the low altitude mode 1 (LEV) aborts the months of September and August are the least and most favorable months, respectively.

Measured Wind Profile

Measured wind profile data from the Gemini IX and Gemini X missions were selected for the following reasons:

a. The months of June and July, as indicated on figure 3, are considered to be the next most favorable months after August.

b. The data shows a realistic effect of actual measured winds on the mode 1 (LEV) abort landing points for a manned mission.

The Gemini IX wind profile measurement is for June 3, 1966 and began at 0539 hours e.s.t. The Gemini X wind profile measurement is for July 18, 1966, and began at 1200 hours e.s.t.

Figures 5 and 6 present the wind profile measured for these two missions. The plots present wind velocity and azimuth as a function of altitude.

Launch and Abort Data

The AS-204 launch vehicle trajectory was chosen for this analysis since the abort studies for this mission have already been conducted using the LEV/CM official data specification criteria from reference 3. The AS-205/101 spacecraft weights, centers of gravity, and parachute design is in the process of being changed, so the AS-204 abort profile was assumed sufficient. In evaluating the land impact problem, it is the elimination of the "sky dive" mode that has the largest effect on land impact.

The mode 1 (LEV) abort trajectories were generated from the nominal launch vehicle operational flight trajectory using the emergency detection system (EDS) limits of ± 3 deg/sec pitch and yaw body rates and $\pm 5^\circ$ pitch and yaw attitudes. These limits only apply to (T + 50) seconds of the launch trajectory and define an abort footprint for each abort time.

The LEV/CM configuration is presented in figure 7.

The following abort cases were considered:

a. No winds

b. September statistical wind data (least favorable month)

c. August statistical wind data (most favorable month)

d. June and July statistical wind data (next two most favorable months)

e. January statistical wind data (most favorable month for aborts after approximately 30 seconds)

f. June and July Gemini measured wind profile data

g. Abort trajectory sensitivity to winds

RESULTS

No Wind Case

Figure 8(a) presents the nominal pad-abort case, abort footprints for 10 through 50 seconds, and the nominal impact point for the 60-second abort case. The reason for the reduction in size of the footprints with increased time is due to the effect of the launch vehicle pitch profile and the abort geometry. All of the aborts land in water that has a depth that is considered acceptable. A safe depth of water is defined as over 10 ft deep at low tide.

September Statistical Wind Data

Figure 8(b) presents the effect of the September statistical winds on mode 1 (LEV) aborts for the nominal pad-abort case, footprints for 10 through 50 seconds and the nominal impact points for 60 and 62 seconds. Also shown are the positions at the time of abort from lift-off pad through 60 seconds. September is considered to be the worst month case. The effect of the winds shift the footprints farther inland than any of the other months. A safe water landing is not assured except for approximately half of the 10-second footprint and when the launch vehicle reaches approximately 62 seconds of flight time, or the mode 1c region.

The 40-second abort footprint is the farthest inland case and after 40 seconds the footprints shift back in the offshore direction due to the switching from the mode 1a to the mode 1b abort region.

August Statistical Wind Data

Figure 8(c) presents the effect of the August statistical winds on mode 1 (LEV) aborts for the nominal pad-abort case and footprints for 10 through 50 seconds of flight time. August is considered to be the most favorable month. The effect of the winds allows a safe water landing at 50 seconds of flight time. However, there is still a land impact problem or unsafe depth of water landing from part of the 10-second footprint up to approximately 50 seconds of flight time.

June and July Statistical Wind Data

Figures 8(d) and 8(e) present the effects of the June and July statistical winds on mode 1 (LEV) aborts for the nominal pad-abort case and footprints for 10 through 50 seconds of flight time. The months of June and July are considered to be the next two more favorable months after August. The abort footprints for both of these months are almost identical; however, the land impact problem or unsafe depth of water landing still exists as for the month of August.

January Statistical Wind Data

Figure 8(f) presents the effect of the January statistical winds on mode 1 (LEV) aborts for the nominal pad-abort case and footprints for 10 through 45 seconds and the nominal 50-second abort impact point.

The month of January is considered to be a more favorable month for aborts after approximately 30 seconds. The effect of the winds after 30 seconds shift the abort footprints back in the offshore direction. However, the land impact problem or unsafe depth of water landing still exists.

June and July Gemini Measured Wind Profile Data

Figures 8(g) and 8(h) present the effects of the June and July measured wind data from the Gemini IX and Gemini X missions on mode 1 (LEV) aborts. The June Gemini IX wind profile measurement began at 0539 hours e.s.t. and the July Gemini X wind profile measurement began at 1200 hours e.s.t.

The results for the June Gemini measured wind profile in figure 8(g) shows the nominal pad-abort case and footprints for 10 through 40 seconds of flight time. This particular measured wind profile shows land impact or unsafe depth of water landing for parts of the 10-, 20- and 30-second abort footprints.

The results for the July Gemini measured wind profile in figure 8(h) shows the nominal pad-abort case and footprints for 10 through 40 seconds of flight time. This particular measured wind profile shows all safe water landings.

Abort Trajectory Sensitivity to Winds

In evaluating the land impact problem during mode 1 (LEV) aborts it was determined that the abort trajectory is very sensitive to winds, particularly the attitudes during the thrust phase. For this sensitivity analysis the statistical wind for the months of September (least favorable) and August (most favorable) were considered.

Figure 9(a) presents the results of the sensitivity analysis (September winds) for a nominal 30-second abort case.

This plot shows the abort profiles (altitude versus range) for a nominal 30-second case with (1) winds applied on the complete abort trajectory, and (2) winds applied on the abort trajectory after the thrust phase.

The data is presented in two plots; altitude versus down-range abort profile, and altitude versus up-range abort profile. The data is presented in this manner because the abort trajectory does not pass directly over the launch pad; therefore, the range never goes to zero.

Comparison of the two abort cases shows that winds on the abort trajectory produce different abort profiles. This results in deploying main chutes at different altitudes; therefore, the time on the chutes is different.

These two abort trajectories yield different impact points with a difference in range, ΔR, of approximately 1400 ft.

Figure 9(b) presents the results of the sensitivity analysis for the month of August. This plot shows the same effect of winds applied to the abort trajectory as for the month of September. However, for this case the ΔR is approximately 500 ft.

An analysis was also made for application of winds to the abort trajectory from drogue chutes deployed to impact. This showed the same abort profile as the application of winds after the thrust phase case. The difference, ΔR, between the two abort cases was negligible and therefore not shown. This analysis shows that winds during the canard phase have very little influence on the abort profile. However, winds during the thrust phase greatly influence the abort trajectory due to the sensitivity of the attitudes.

CONCLUSIONS

The conclusions from this analysis are:

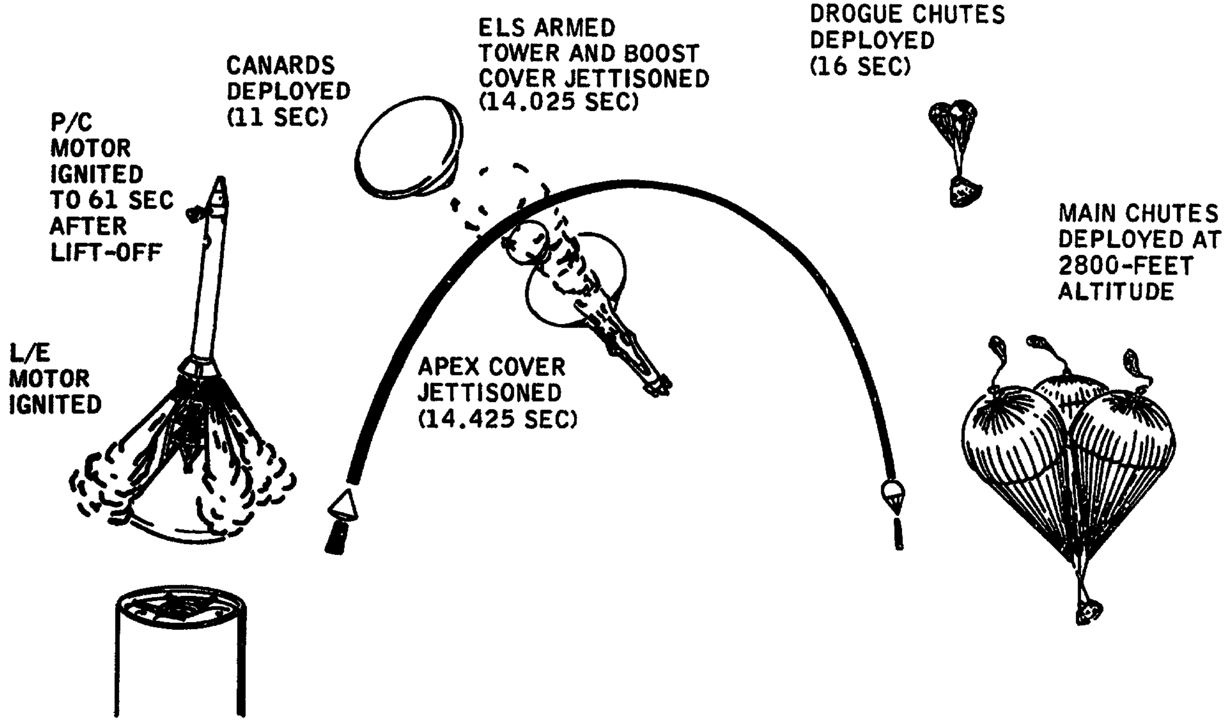
a. The probability of a land impact for mode 1 (LEV) aborts from the Saturn IB vehicle exists and greatly enhances the wind restriction on manned missions.

b. It is necessary, therefore, to measure the wind velocity and azimuth on the day of launch. This data should then be input into the mode 1 abort real-time simulation to determine if it is severe enough to hold the mission because of a land impact possibility.

c. From this analysis, a reduction in the probability of a land landing may be accomplished by restricting the month of launch to August (most favorable), June, or July.

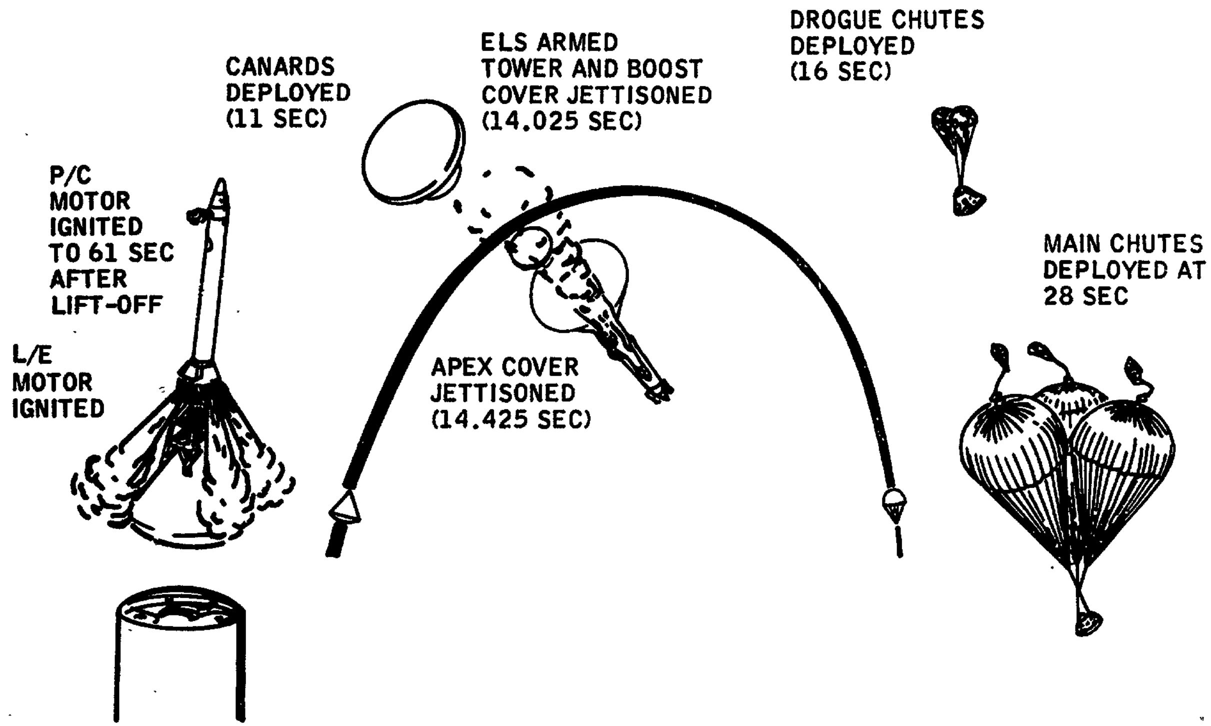
d. It is essential that wind be applied to the entire abort trajectory due to the sensitivity of the attitudes of the LEV to winds during the thrust phase. This method is considered more accurate in predicting land impacts.

This document considered only the EDS limits for the land impact analysis; however, further analysis will consider the effect of a 3σ (LEV + SC), 3σ misalignment of the LEV thrust vector in the up-range direction, etc.



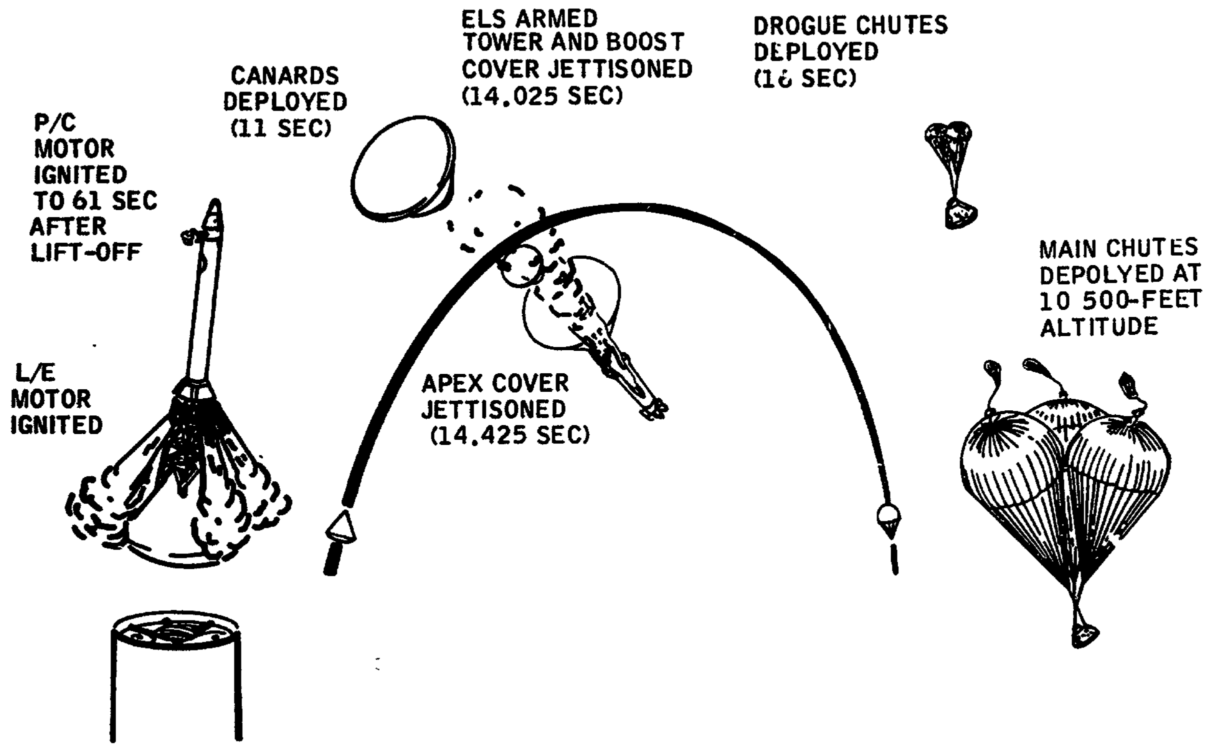
(a) Mode 1 aborts.

Figure 1.- LEV abort sequences.



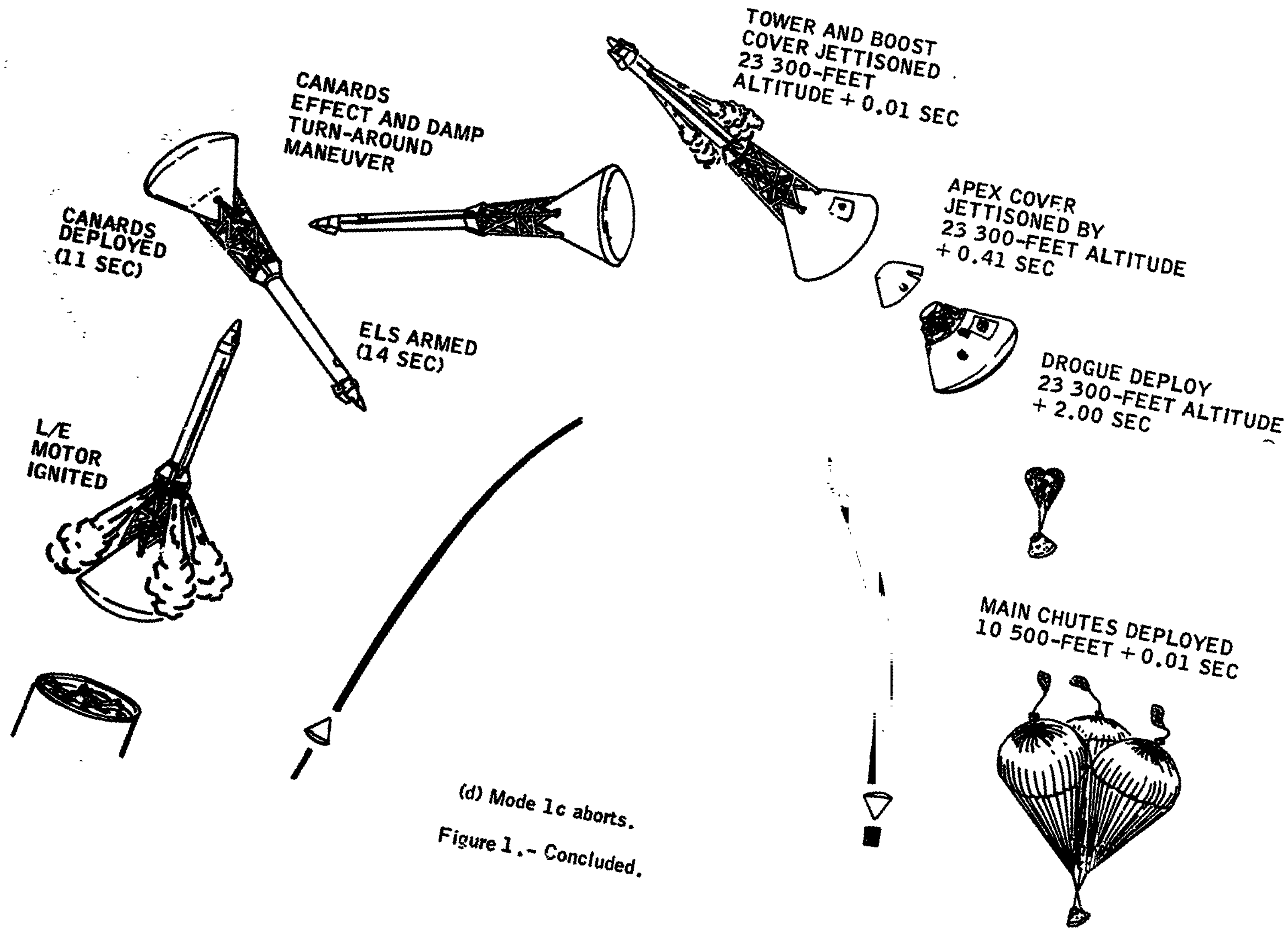
(b) Mode 1a aborts.

Figure 1.- Continued.



(c) Mode 1b aborts.

Figure 1.- Continued.



(d) Mode 1c aborts.

Figure 1.- Concluded.

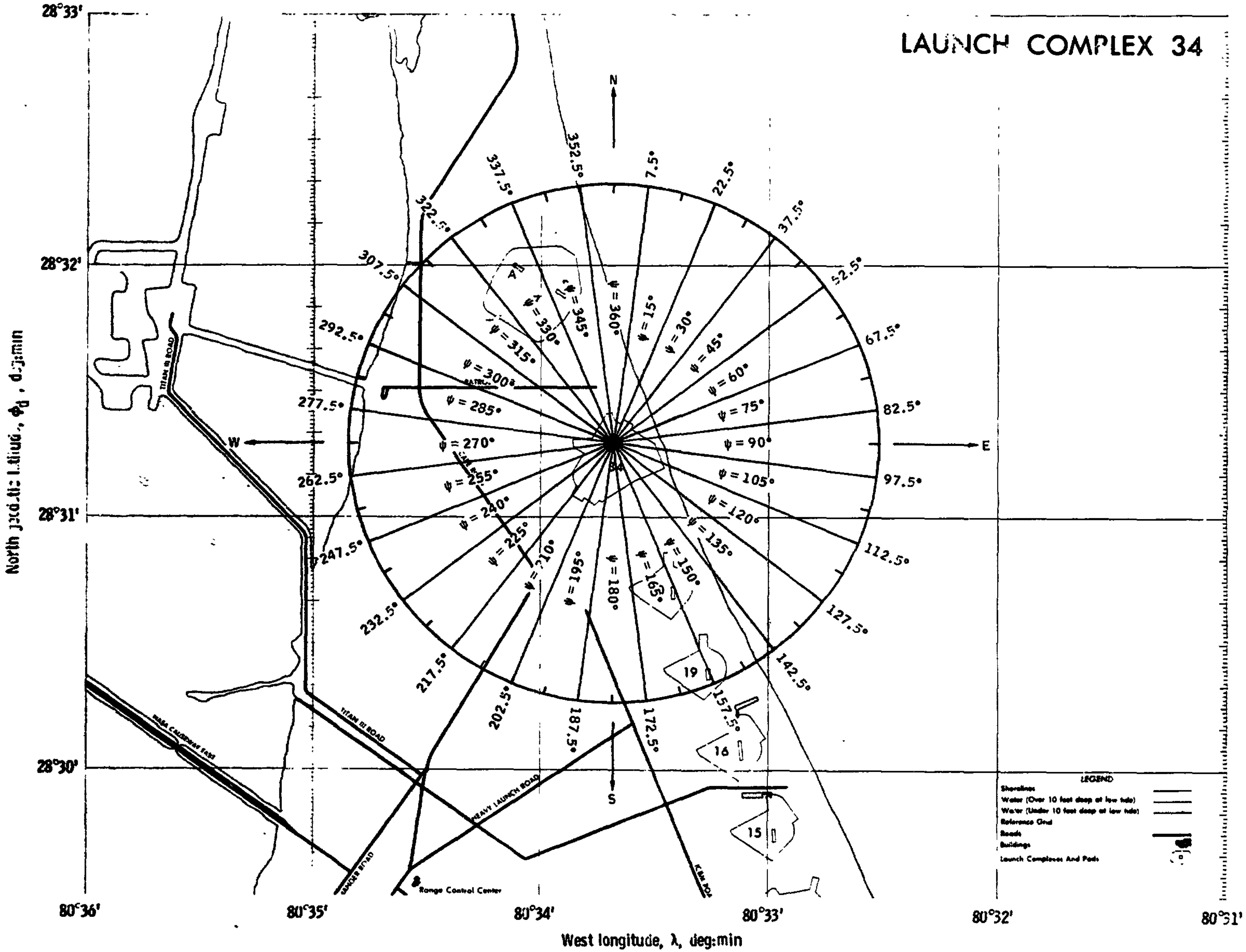
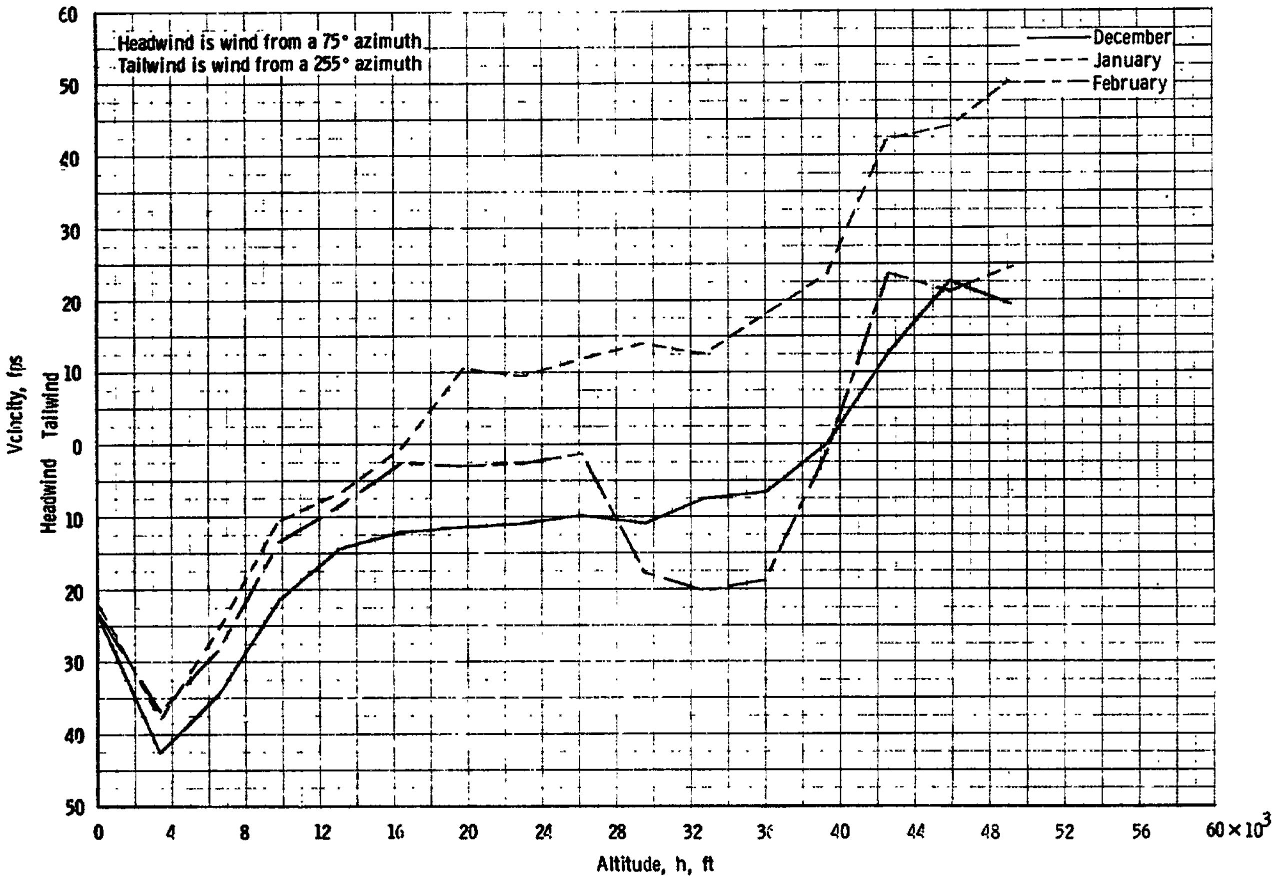
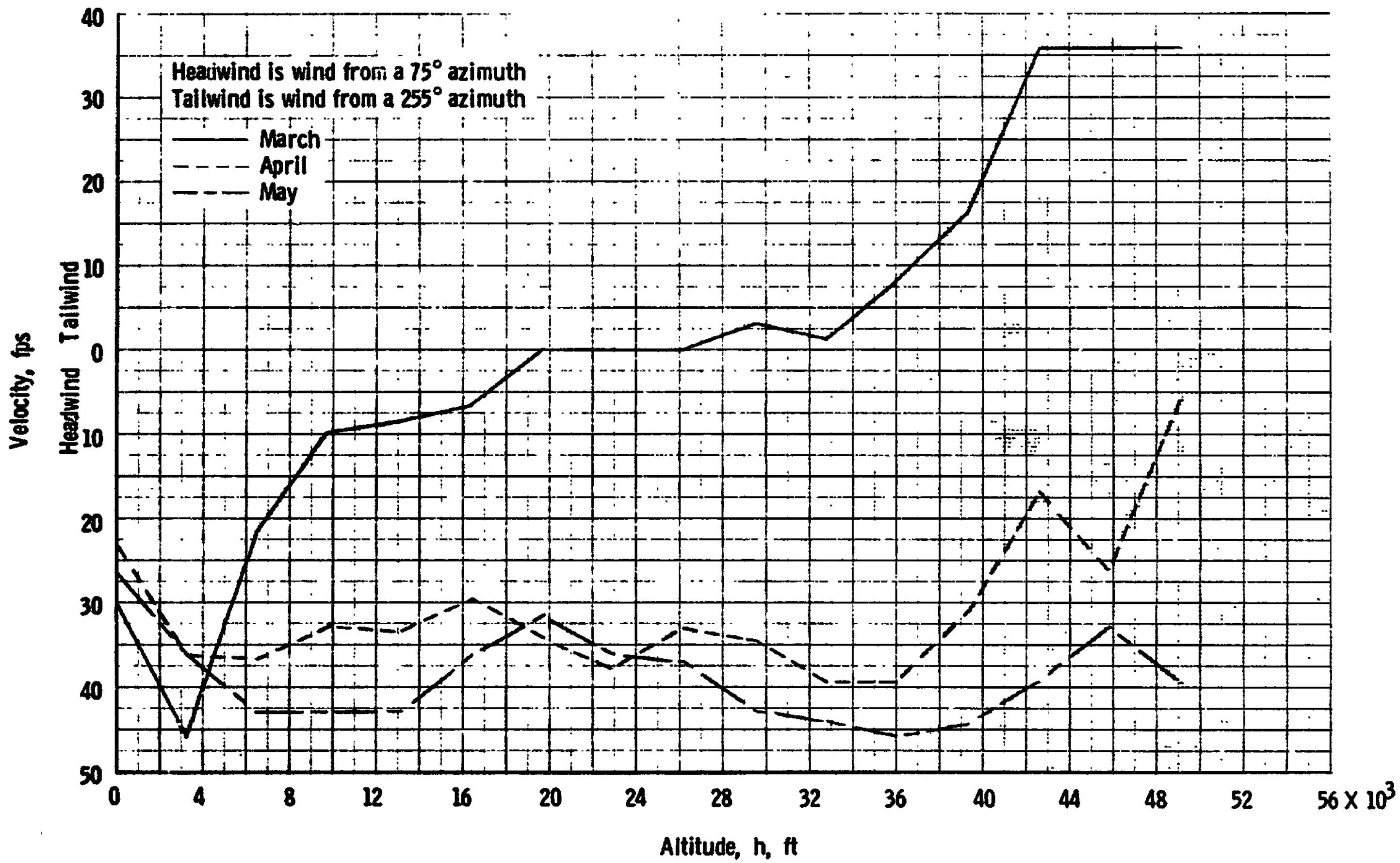


Figure 2. - Range of azimuths, ψ, of statistical wind data.



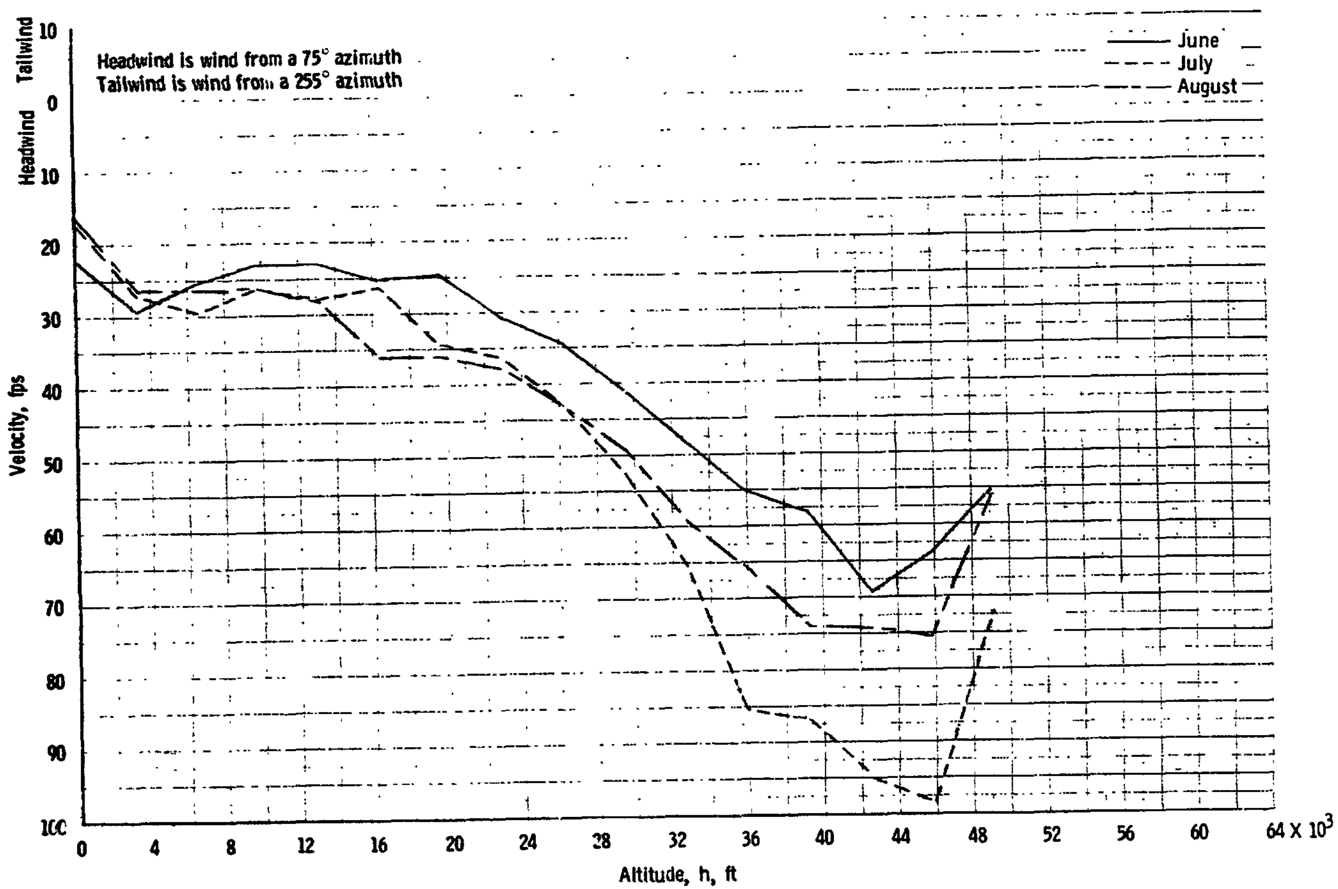
(a) Winter.

Figure 3. - Measured headwind components for a 75-degree flight azimuth.



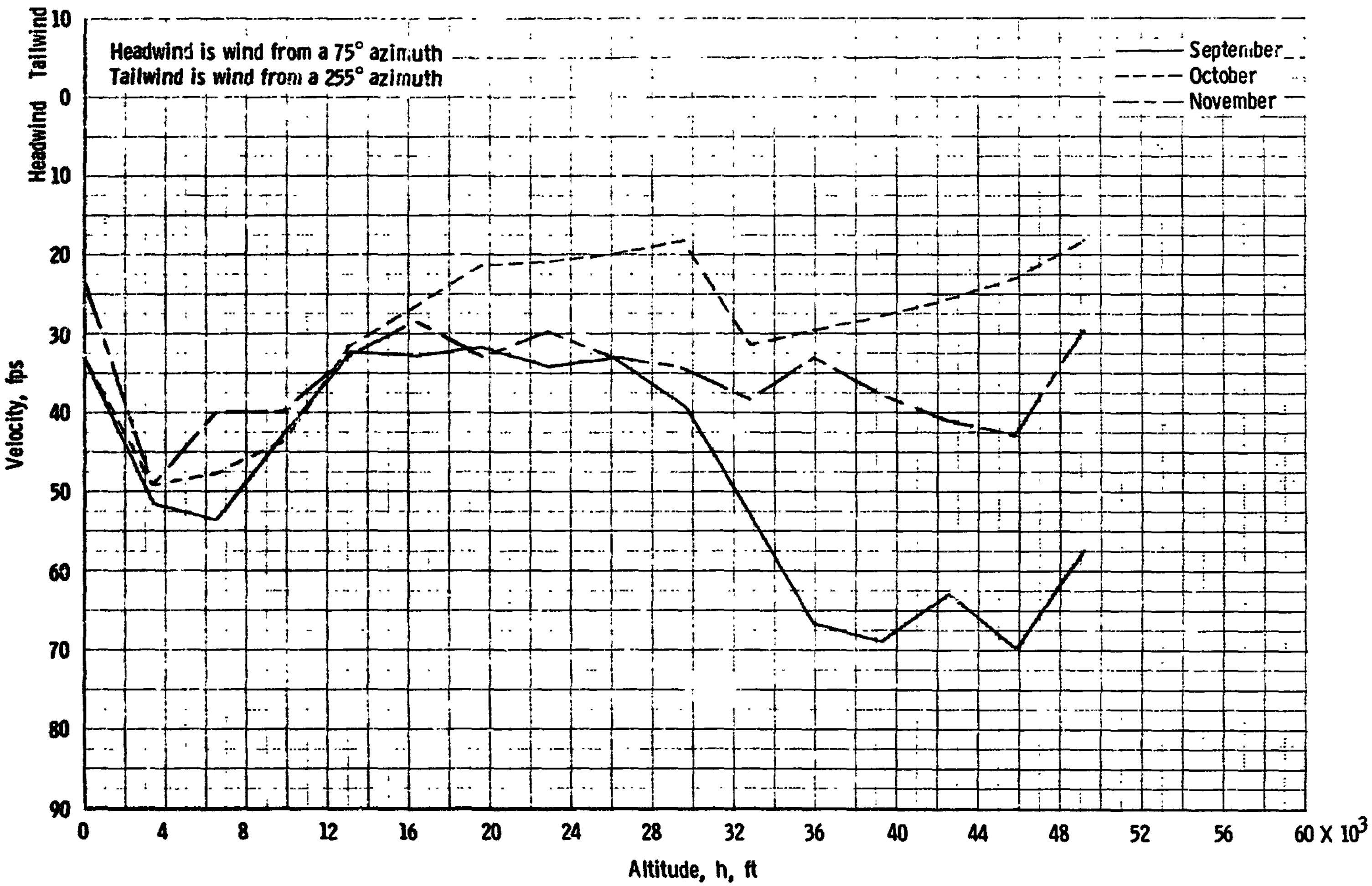
(b) Spring.

Figure 3.- Continued.



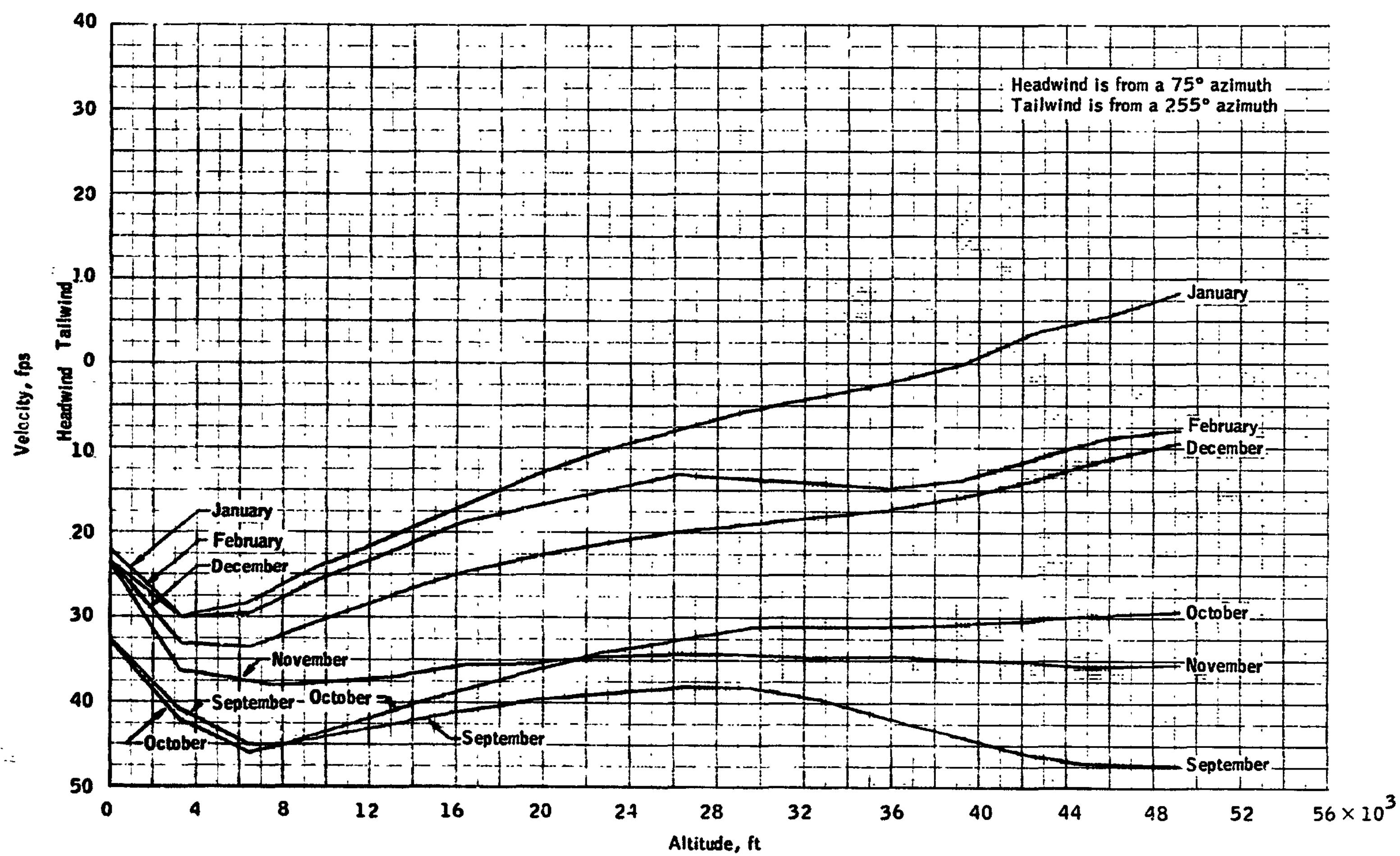
(c) Summer.

Figure 3.- Continued.



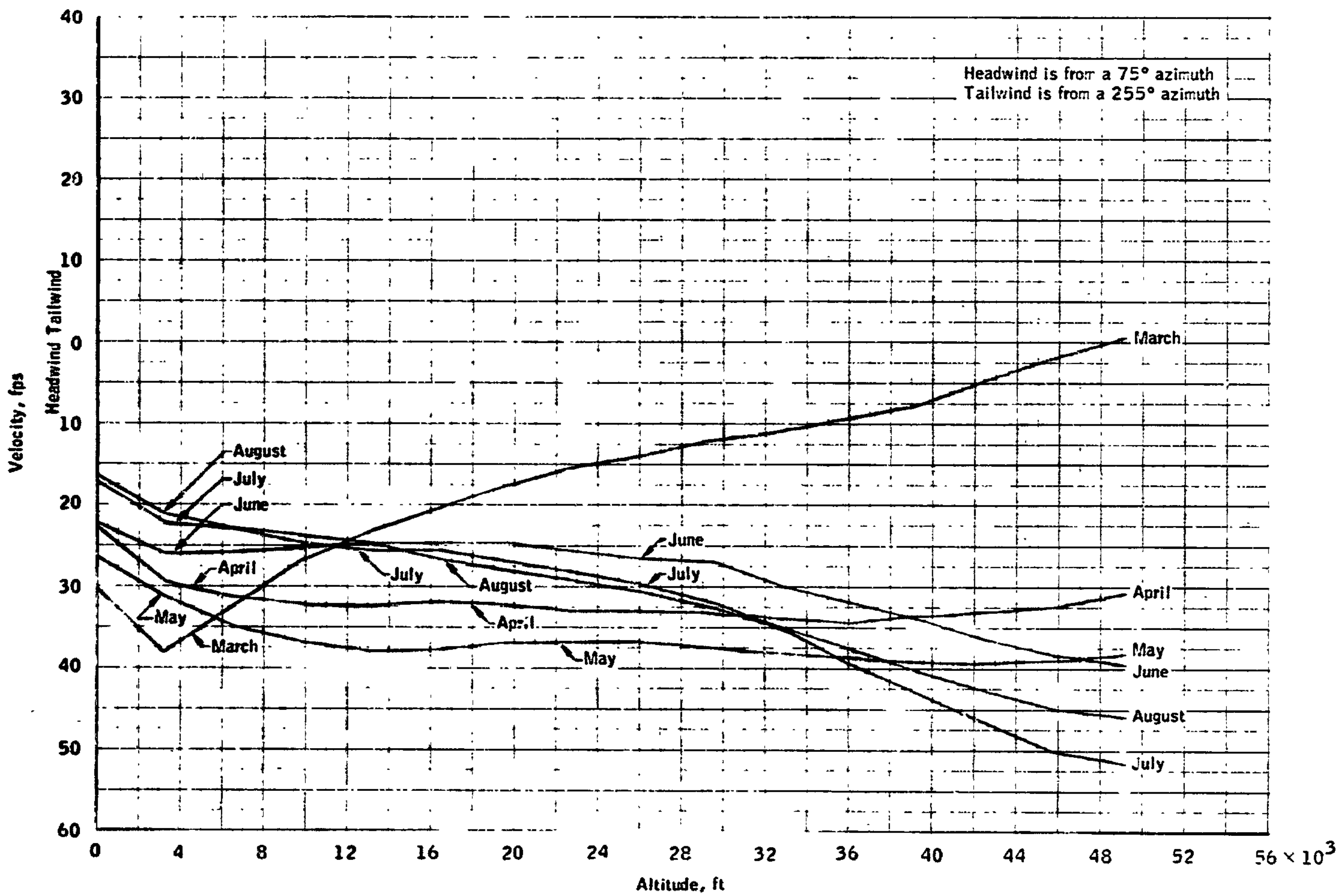
(d) Fall.

Figure 3.- Concluded.



(a) Fall and winter.

Figure 4.- Average headwind components for a 75-degree flight azimuth.



(b) Spring and summer.

Figure 4.- Concluded.

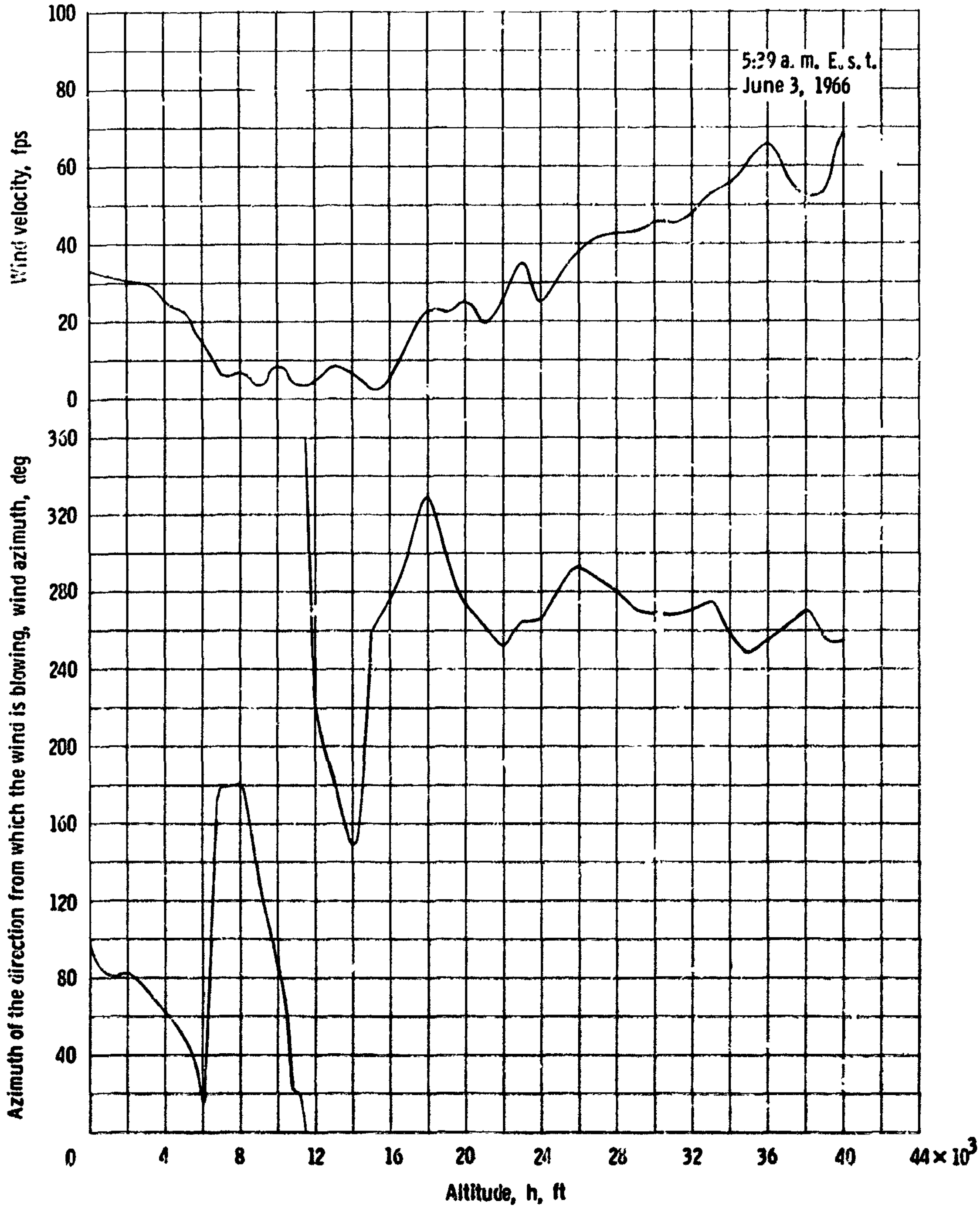


Figure 5. - Measured wind profile for the Gemini IX mission.

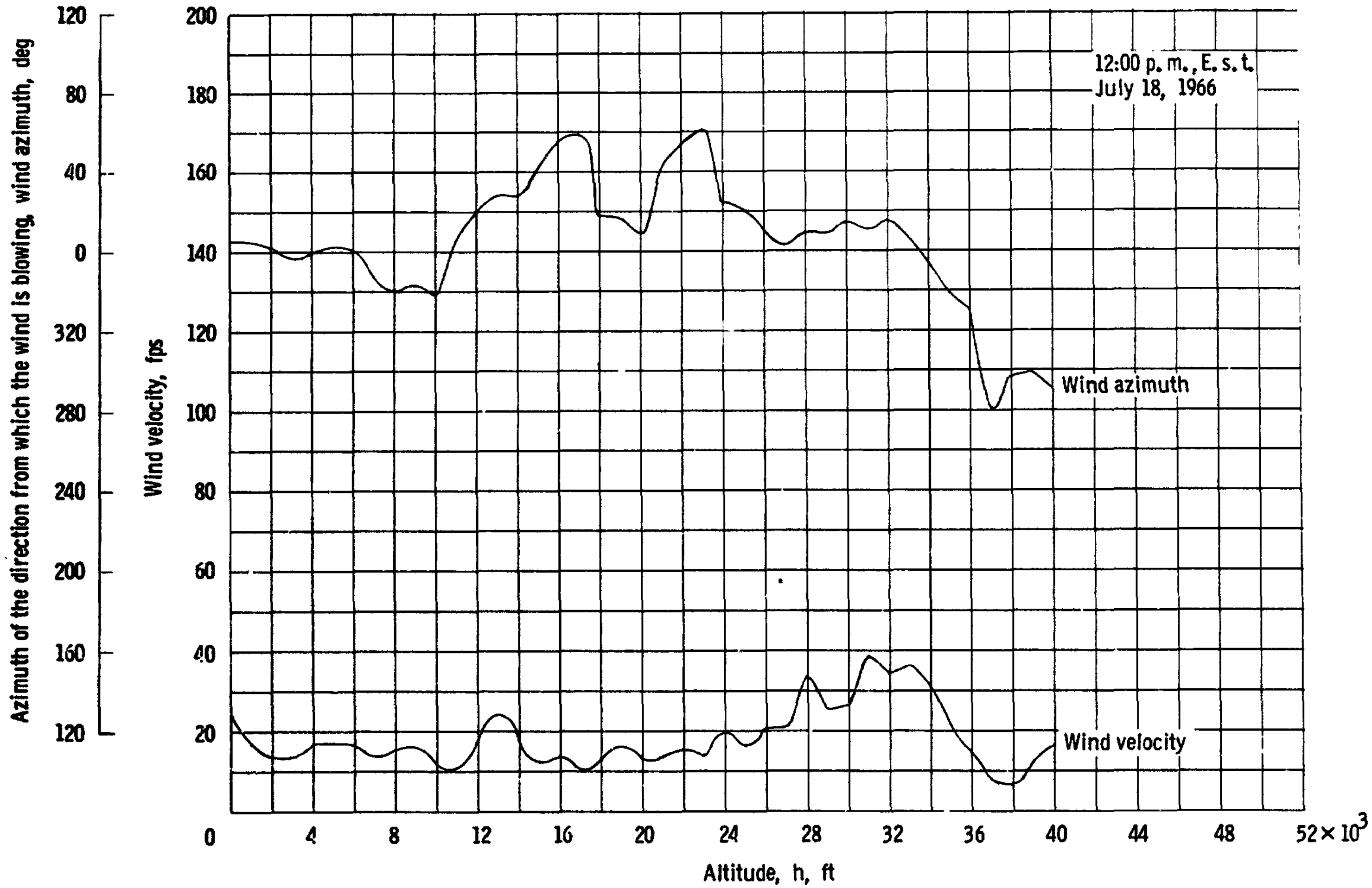


Figure 6. - Measured wind profile for the Gemini X mission.

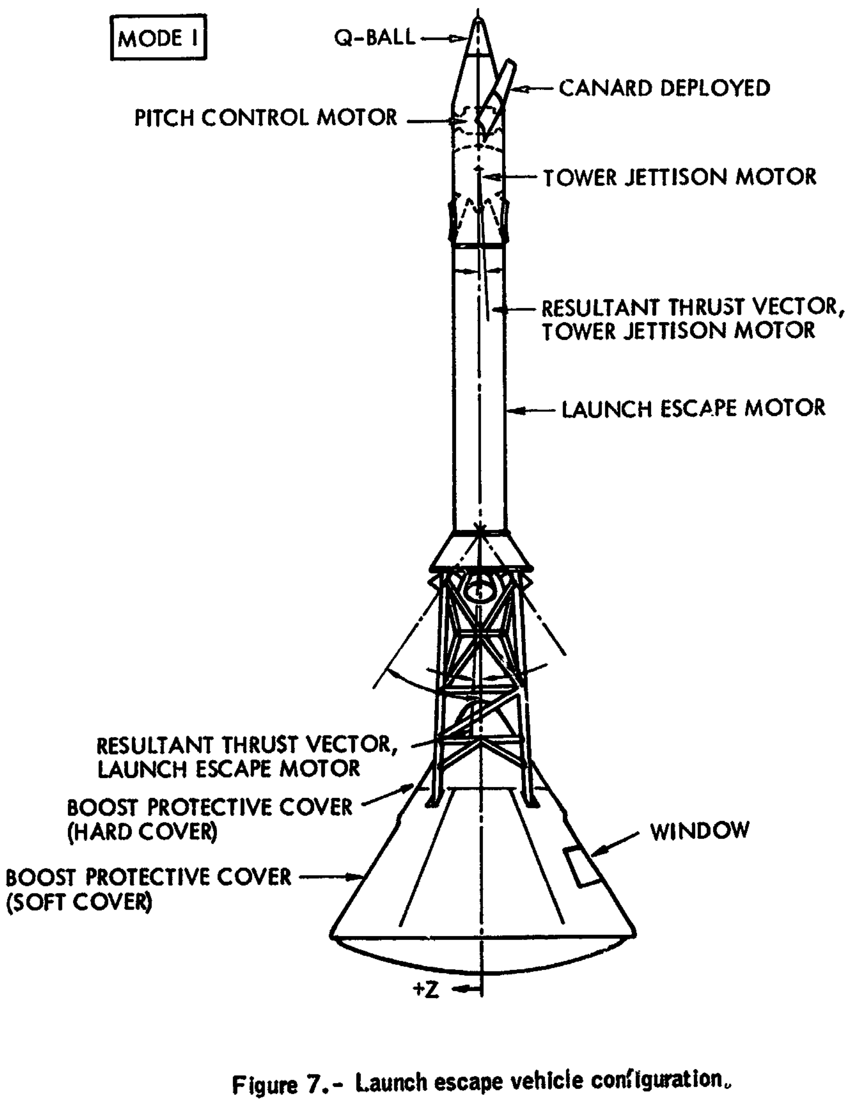
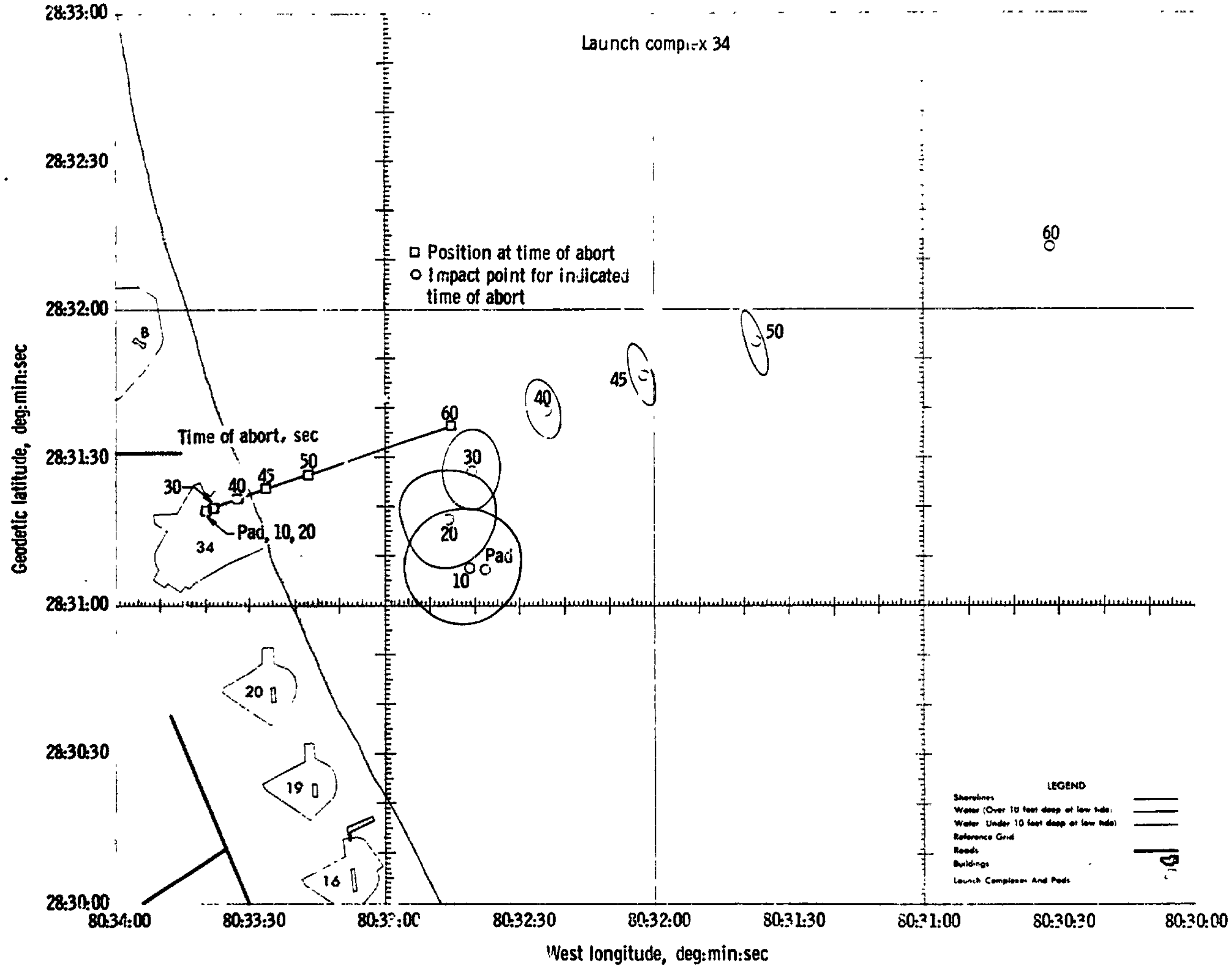
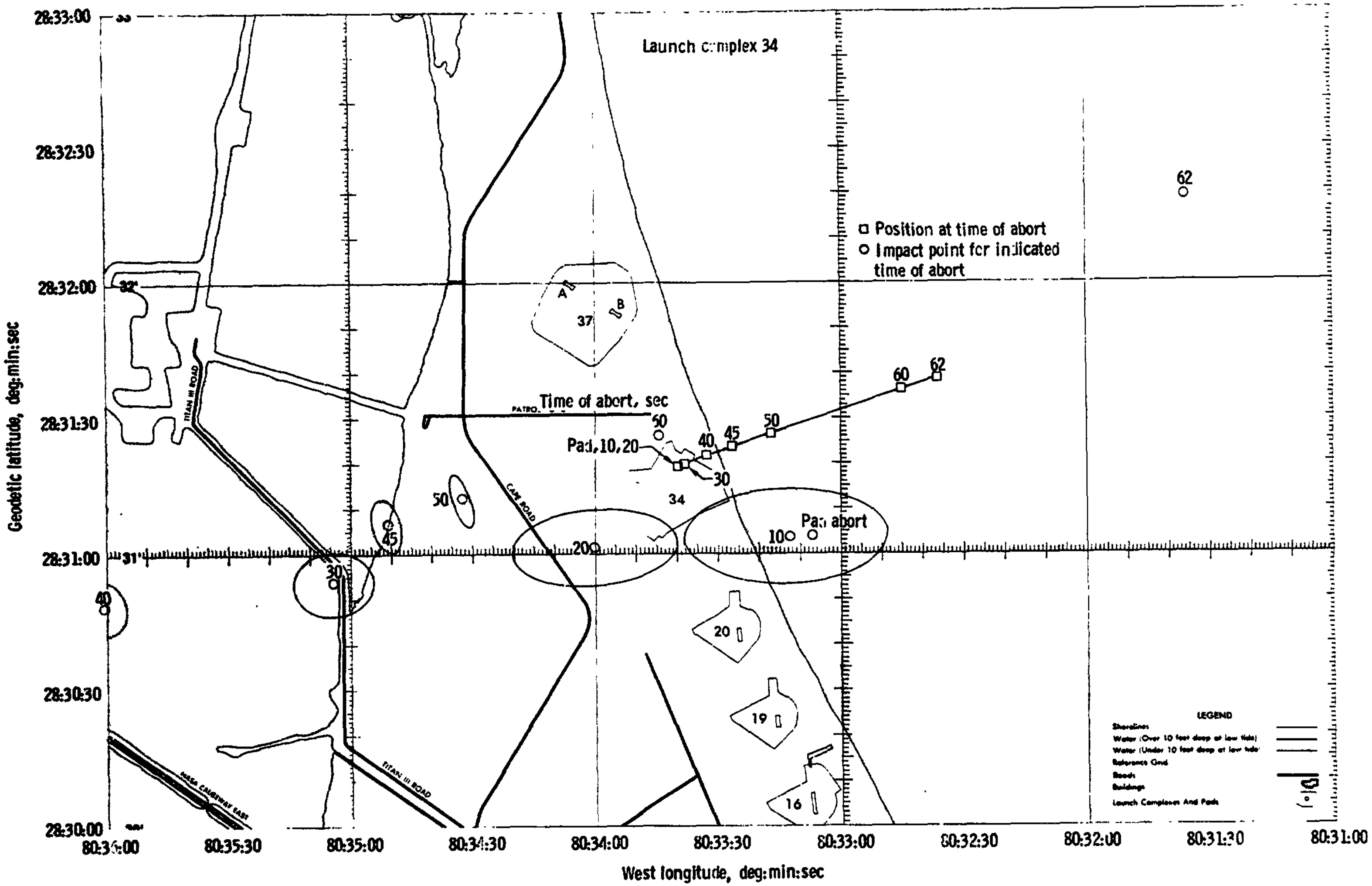


Figure 7.- Launch escape vehicle configuration.



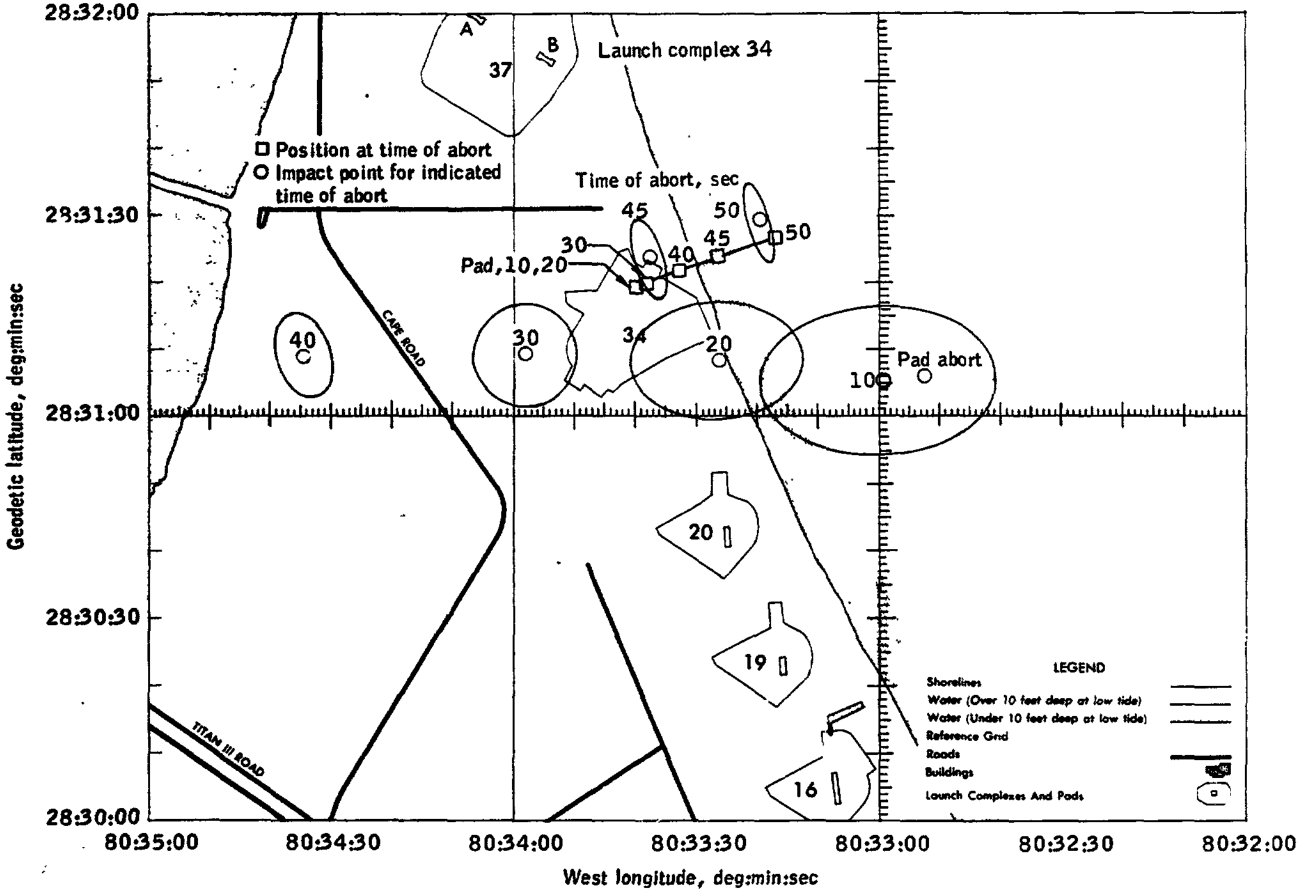
(a) No wind.

Figure 8.- Mode I (LEV) aborts.



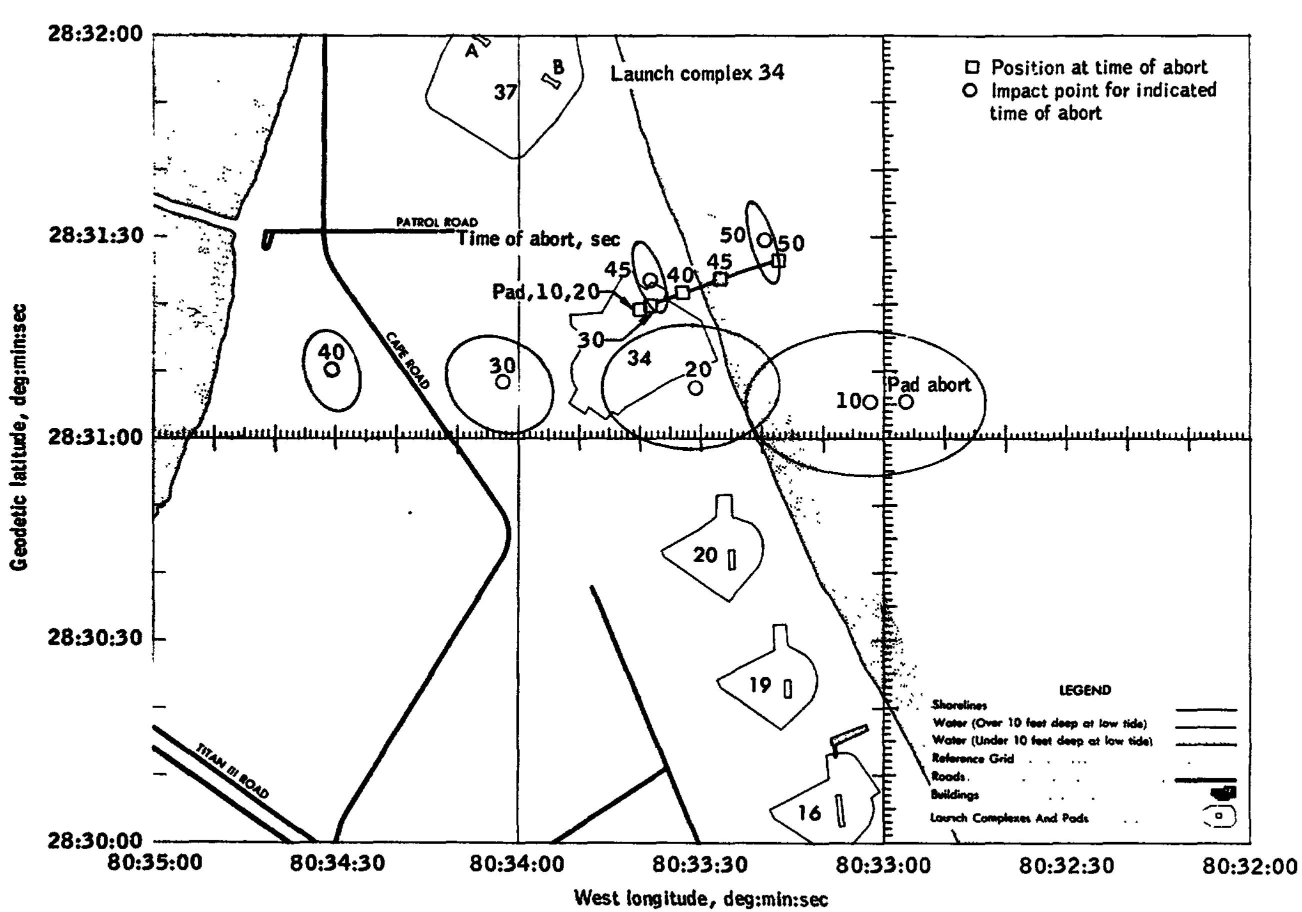
(b) September winds.

Figure 8.- Continued.



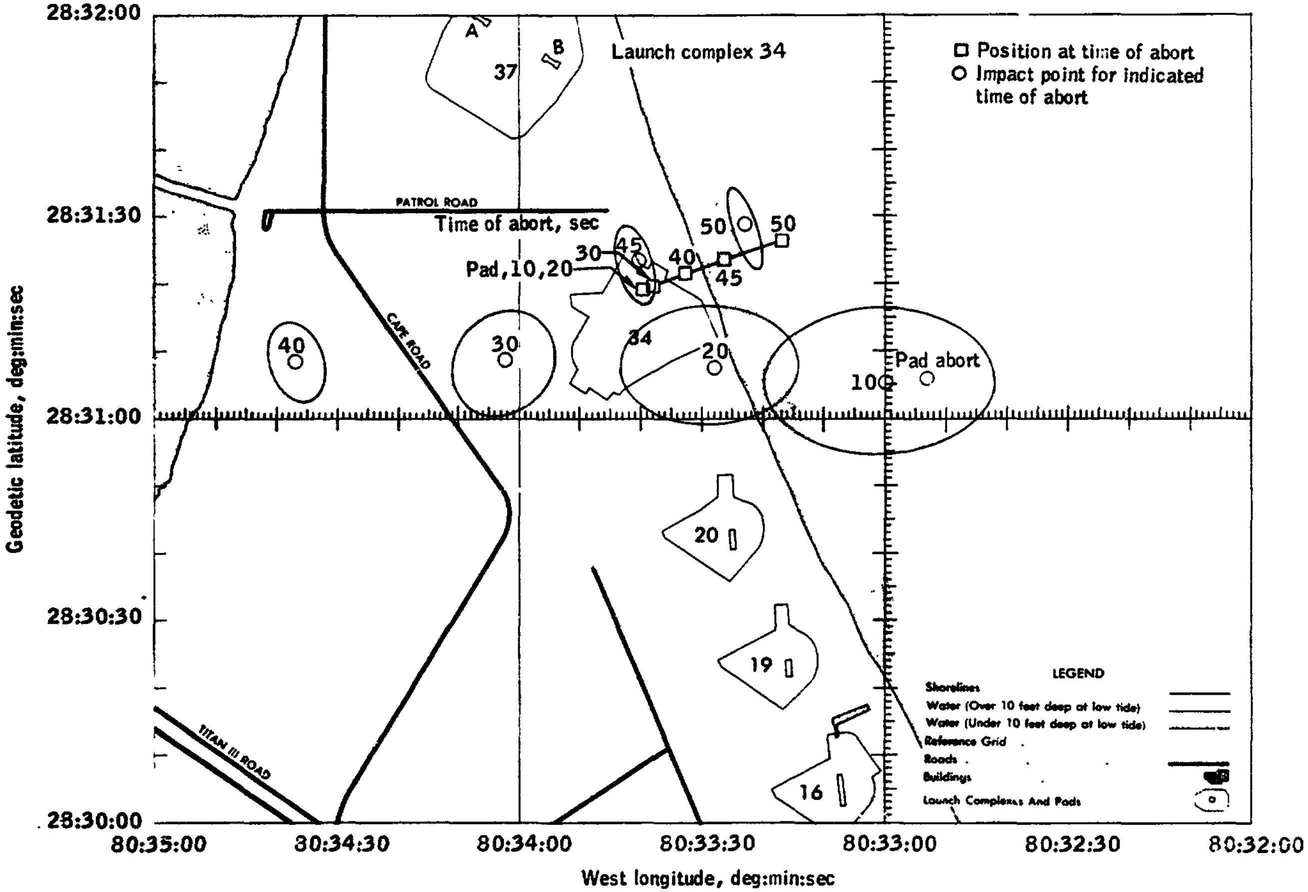
(c) August winds.

Figure 8.- Continued.



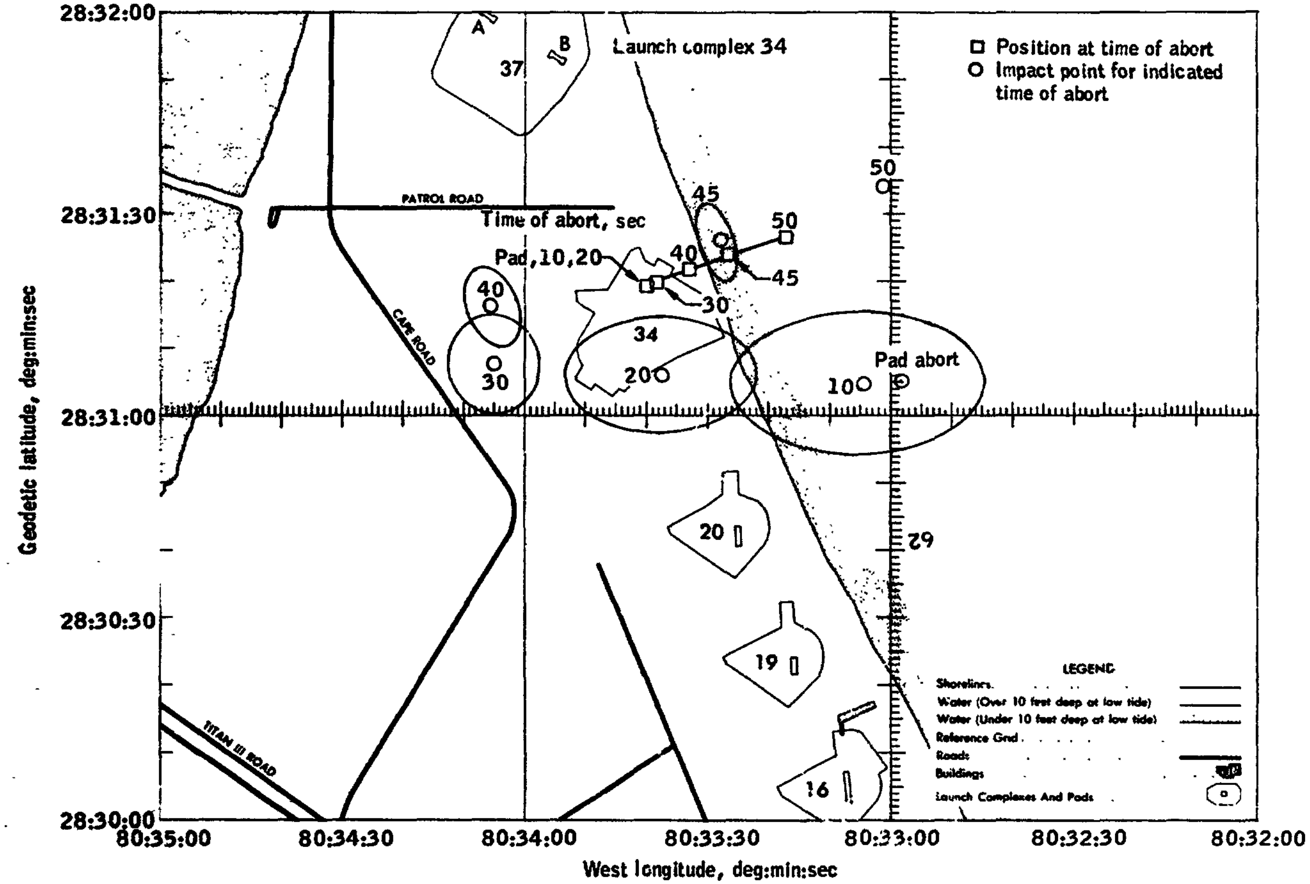
(d) June winds.

Figure 8.- Continued.



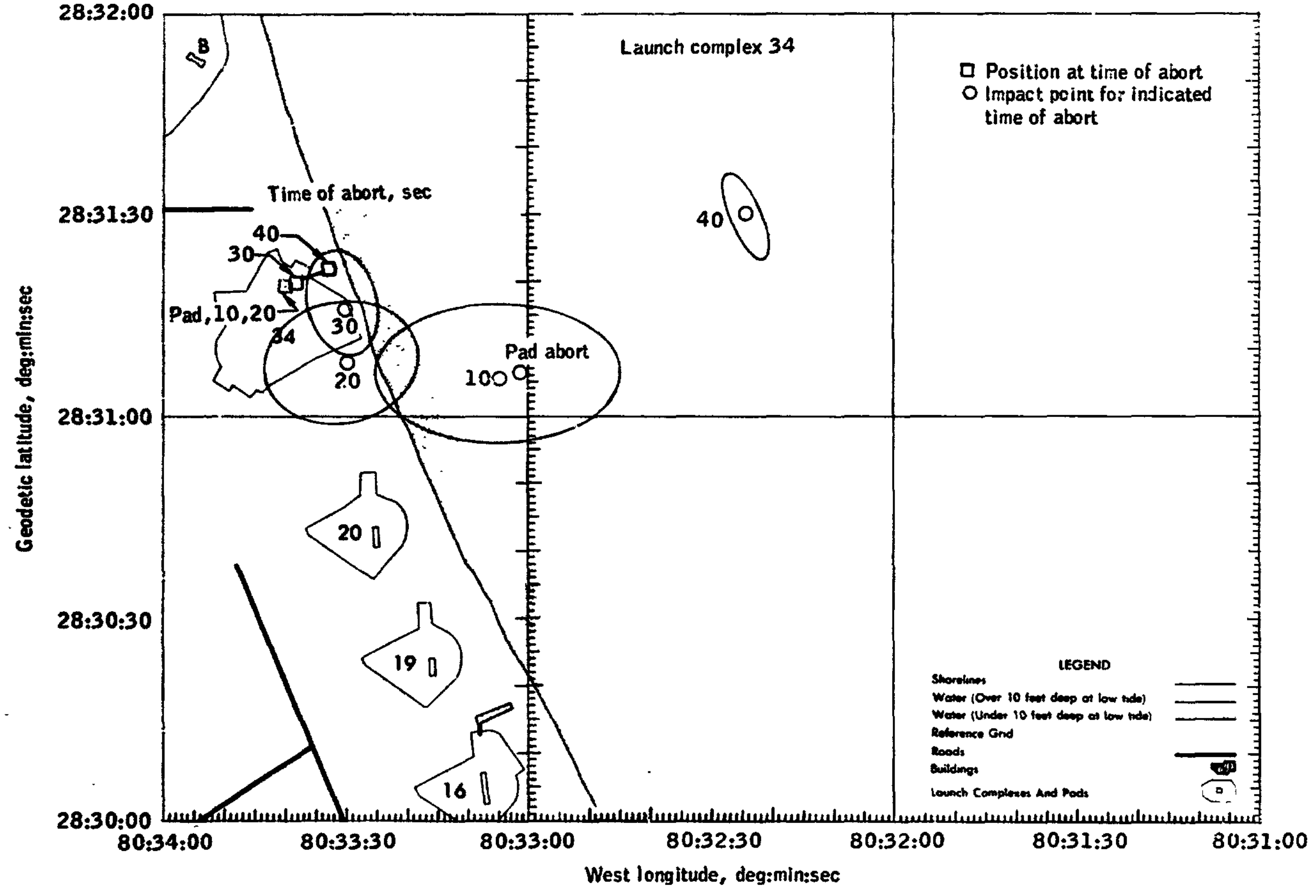
(e) July winds.

Figure 8.- Continued.



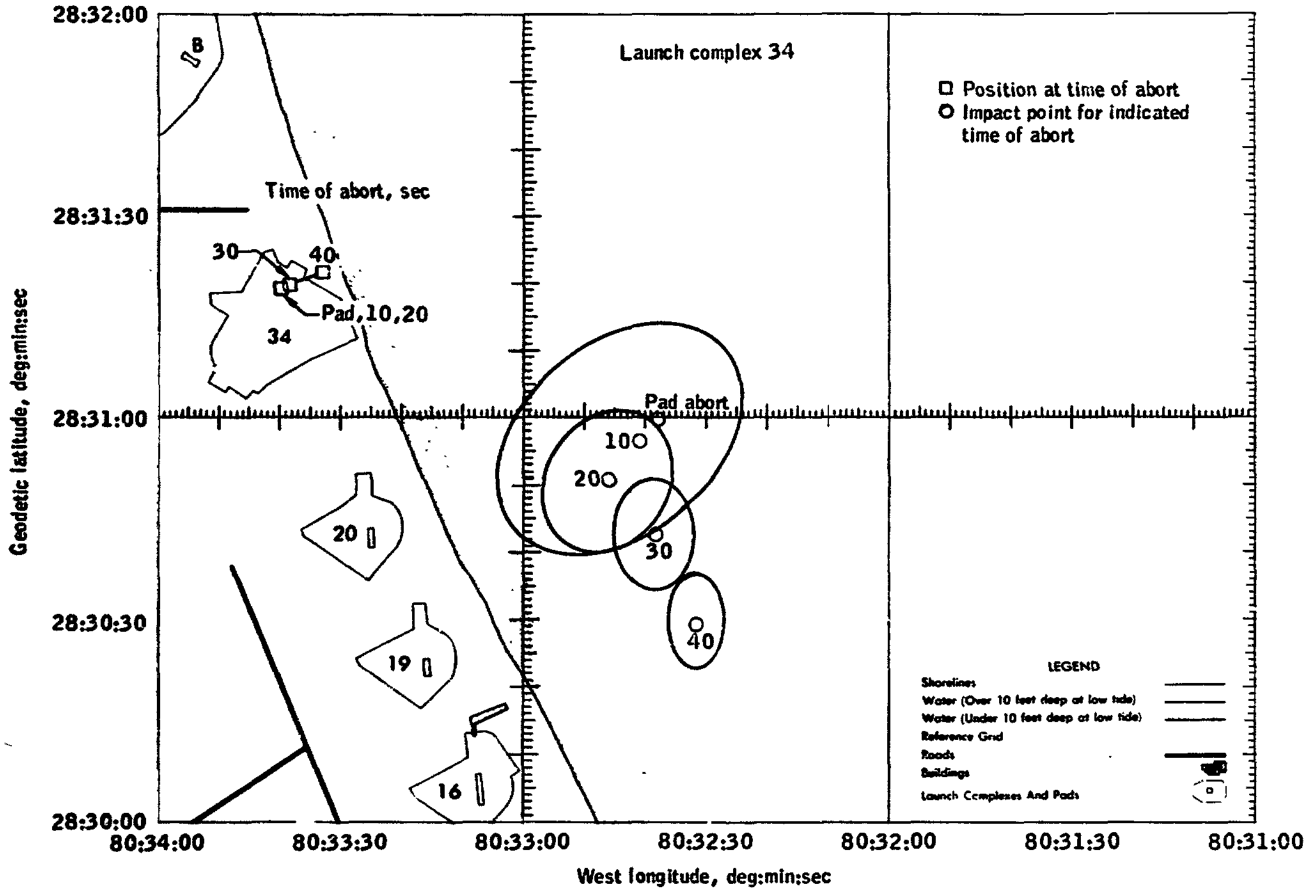
(f) January winds.

Figure 8.- Continued.



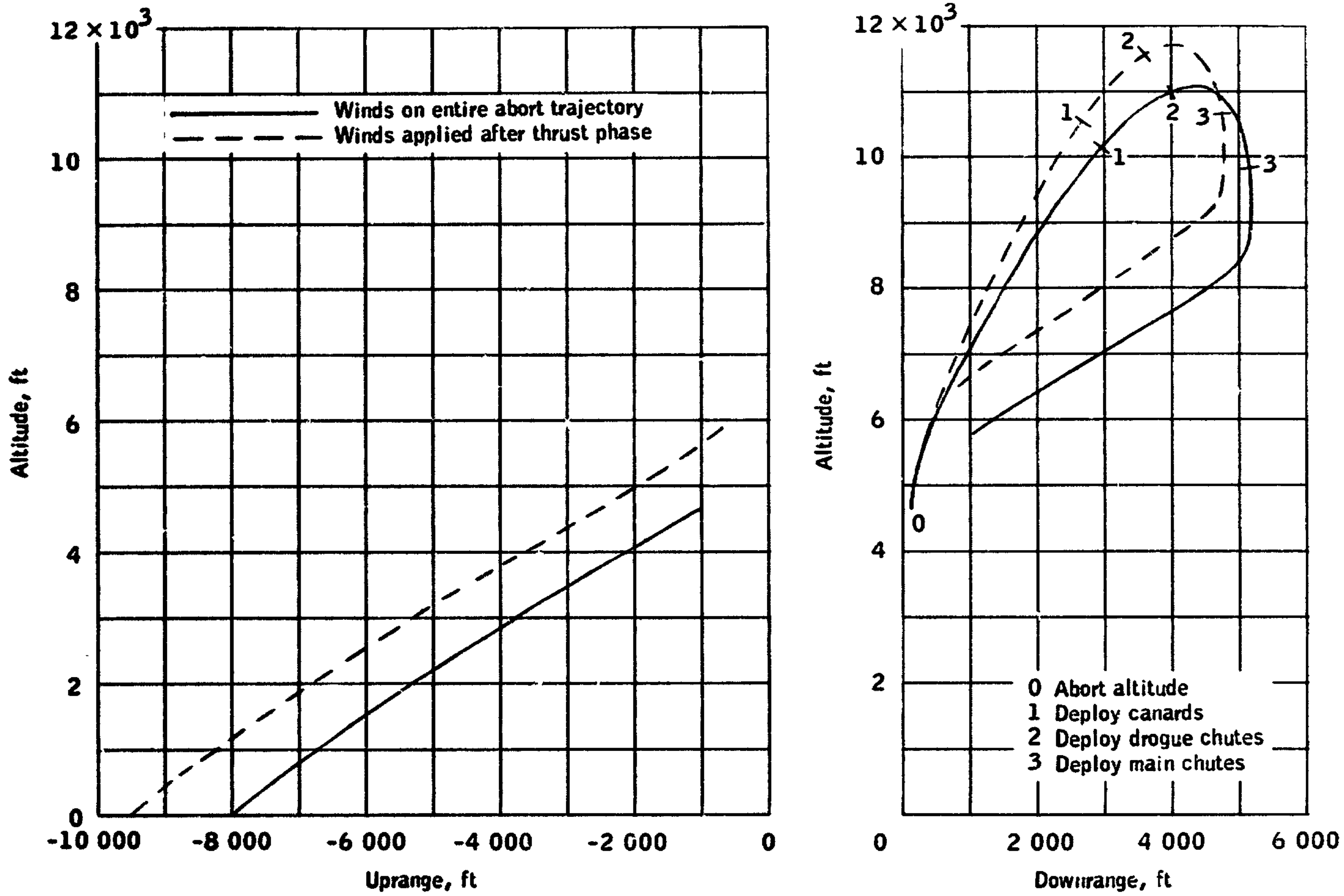
(g) Gemini IX June measured wind.

Figure 8.- Continued.



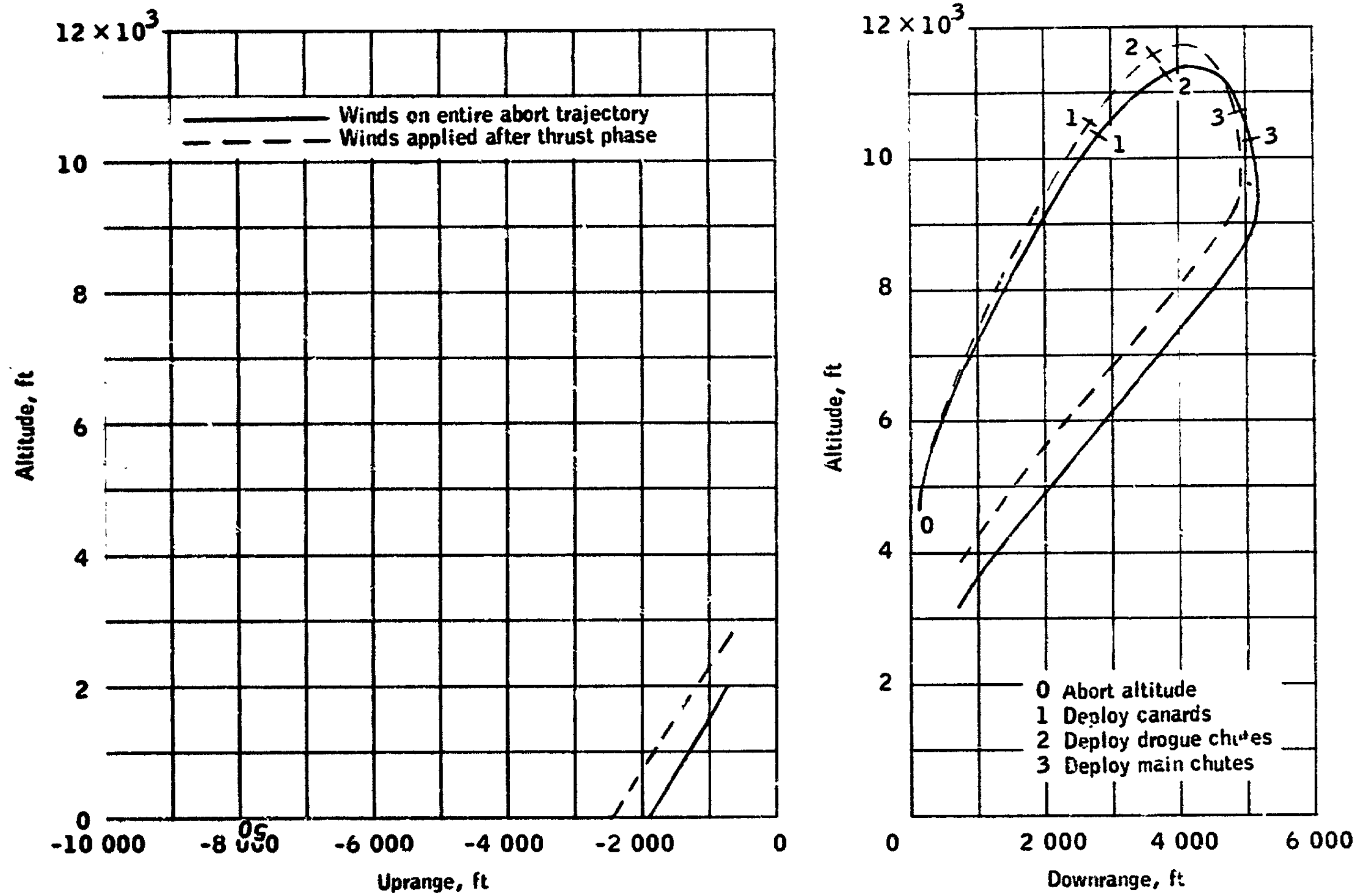
(h) Gemini X July measured wind.

Figure 8.- Concluded.



(a) September winds.

Figure 9.- Sensitivity analysis for a nominal 30-second Mode I (LEV) abort.



(b) August win. .

Figure 9.- Concluded.

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